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Electrophysiological characteristics of undergrowth shrubs in the forest-steppe zone of western Ukraine

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Abstract. The article reviews the electrophysiological characteristics of pre-cambial phloem material in undergrowth shrubs. The electrophysiological properties of hazel (*Corylus avellana* L.), elder (*Sambucus nigra* L.) and other undergrowth shrubs are compared, as well as how these characteristics change depending on stand density indices. Differences in electrophysiological characteristics reveal the crucial role of light for the growth, development, and persistence of undergrowth shrubs. I suggest that a quantitative assessment of electrophysiological characteristics should be undertaken when managing forest stands for the creation of desirable undergrowth.

Key words: electrophysiological characteristics, dielectric parameters, understorey, impedance, polarization capacity, shrubs, stand density.

1. Introduction

An understorey is an important element of the forest ecosystem (Morozov 1926; Ivanitsky 1939; Vysockyj 1983; Gil 2010). While biological characteristics of undergrowth shrubs have been a subject of the accurate research, their electrophysiological characteristics such as bioelectrical potential (impedance and polarization capacity) have been less studied. In environmental research such characteristics are commonly used regarding trees (Mac Dougall 1988; Krynic'kyj 1992; Zaika 2004; Lavnyj, Krynic'kyj 2011) as integral indices of the intensity and specific character of day's, seasonal and ontogenetic physiological and biochemical processes. These characteristics are also used to characterize general plants' condition.

The pre-cambial group of tree and shrub tissues consists of cambium, phloem, and sapwood. These tissues are characterized by high physiological activity. They are susceptible to plants' condition changes and are easily detected by measurement instrument's sensors. Their electrical characteristics differ significantly from the characteristics of other tissues. The obtained results of Mac Dougall's (1988), Krynicki's (1992), Zaika's (2004), and Lavnyja and Krynicki's (2011) research have indicated that impedance and polarization capacity correlate either moderately or closely with intensity of the tree growth in various growth stages of the stand, with the phytomass growth, plants' location, and with the extent of tree damages caused by insects. Impedance of pre-cambial tissues of trees in the predominant layer is lower than that of trees in other layers. Moreover, there is a distinct relation between polarization capacity, growth, and biomass of the assimilation apparatus. Electrophysiological characteristics of the understorey have not been studied yet, either in the forest-steppe zone of western Ukraine or in the rest of the natural zone of the region. The aim of this study was to compare the electrophysiological characteristics (impedance and polarization capacity) of shrub tissues in the understorey of the *Carpinetum betuli* in the forest-steppe zone of western Ukraine.

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2. Research subject

Research was conducted in Tarnopol region, in the "Medobory" reservoir (Wiknianskie forest district) and in Tarnopolskie forest inspectorate (Mykulyneckie forest district). This is a composition of the "Medobory" reservoir (Wiknianskie forest district), where the hazel understorey was found: 10Db (10 Oak) and admixture of species such as hornbeam, lime, and northern red oak. Stand density index was 0.7, and age 60 years. Research of the black elder understorey was conducted in Wiknianskie forestry district, quarter 18, Gostra Mountain, in the middle age *Carpinetum betuli* 3Db7Gb (3 Oak 7 Hardwood). Studies of electrophysiological characteristics of shrub species were conducted in two places in Wiknianskie forest district: 1) in the first age class thicket after early cleaning, 2) in full-grown broad-leaved stand. There were 12 shrub species in the greenwood without a forest canopy: common hazel (*Corylus avellana* L.), European spindle (*Euonymus europaea* L.) and *Euonymus verrucosus Scorp*., black elder (*Sambucus nigra* L.), common dogwood (*Cornus sanguinea* L.), alder buckthorn (*Frangula alnus* Mill.), common buckthorn (*Rhamnus cathartica* L.), blackthorn (*Prunus spinosa* L.), dog rose (*Rosa canina* L.), water elder (*Viburnum opulus* L.), *Spiraea* L., and common hawthorn (*Crataegus monogyna* Jacq.).

The broad-leaved stand, where a number of shrub species were found under the forest canopy (common hazel, common spindle, *Euonymus verrucosus* Scorp., black elder, common dogwood, and common hawthorn), was characterized as the *Carpinetum betuli* in the fresh deciduous site type of the locally variable species composition: English oak – 20-30%, European ash – 10-20%, Norway maple – 10-20%, hornbeam – 30-60%. The stand was the first age class – 'growing-full-grown'. There was 0.7-0.8 hedge of the stand.

3. Methodology

Dielectric parameters of pre-cambial plant tissues (impedance and polarization capacity) were measured by the measuring instrument RLC-F4320. Measurements were conducted at frequency 1 kHz. Electrodes were placed into the plants' phloems at height 0.20 m at the land level. Distance between the electrodes was 2 cm (Krynicki 1992).

Table 1. Dielectric parameters of undergrowth shrubs in stands with different stand density index

Stand density index	Impedance				Polarization capacity			
	M±m, kΩm	%	t_f	V, %	M±m, nF	%	t_f	V, %
Hazel, Mykulyneckie forest, compartment 20,4 (9.07.2010)								
stand edge – control)	22,9±1,7	100,0	0,00	48,2	1,49±0,12	100,0	0,00	51,6
0,4	20,6±1,3	90,0	1,07	39,2	2,08±0,13	139,6	3,33	37,9
0,8	41,2±4,6	179,9	3,73	45,7	1,16±0,18	77,9	1,53	64,2
Elder, Wiknianskie forest, compartment 29,9 (8.07.2010)								
stand edge – control)	5,6±0,2	100,0	0,00	11,1	3,59±0,13	100,0	0,00	13,0
0,5	11,6±0,9	207,1	6,51	40,2	2,39±0,28	42,7	9,33	59,9
0,6	11,1±0,6	198,2	8,70	27,9	1,87±0,12	66,6	3,89	32,0
0,7	13,8±1,0	246,4	8,04	28,8	1,65±0,10	46,0	11,83	25,2
0,8	16,3±1,6	291,1	6,64	31,5	1,50±0,11	41,8	12,27	22,7
0,9	17,8±0,7	317,9	16,76	19,8	1,44±0,05	40,1	15,44	15,3

M – mean value
m – mean value error
t_f – TF value
V – Coefficient of variation
Confidence interval at α=0,05 is 2,00-2,20

In regard to the most common species in the region – common hazel (*Corylus avellana* L.) and black elder (*Sambucus nigra* L.) – their persistence was defined depending on the hedge. There were 20 repetitions on average. Student's t-test was used for the statistical analysis.

4. Results and discussion

Research results of dielectric parameters of the common hazel and black elder, depending on a hedge of the stand, are presented in table 1. Measurement results (tab.1) indicate that dielectric parameters of the common hazel and black elder change significantly depending on hedges. In regard to common hazel, impedance parameters fluctuate within the scope of 22.9-41.2 kΩm, and polarization capacity within 1.16-2.08 nF. There is considerably lower impedance (circa 10%) observed and significantly higher polarization capacity (circa 39,6%) in the stand of 0.4 hedge than in the control environment (the stand edge). Growing conditions and hazel's persistence get worse in conjunction with the higher hedge. When there is 0.8 hedge, impedance indicator of the hazel goes up to 79.9%, and polarization capacity indicator is reduced to 22.1%. When a hedge is small, the growing conditions are the best for common hazel. A variability coefficient of impedance is lowest when there is 0.4 hedge (39.2%). Though, it is higher both in the stand edge (48.2%) and when there is 0.8 hedge (45.7%). A variability coefficient of polarization capacity changes from 37.9% to 64.2%.

Table 2. Dielectric parameters of undergrowth shrubs in forest with stand density index 0,7–0,8 (in denominator) and in the open-space (in numerator), in forest district Wilkniańskie, compartment 18, Gostra Mountain; 27.06.2011)

Stand density index	Impedance				Polarization capacity			
	M±m, kΩm	%	t_f	V, %	M±m, nF	%	t_f	V, %
Corylus avellana L.	34,4±1,0 / 48,0±6,6	100,0 / 139,5	0,00 / 2,04	14,9 / 36,5	1,05±0,06 / 0,56±0,08	100,0 / 53,3	0,00 / 4,90	27,0 / 38,2
Euonymus europaea L.	8,5±0,4 / 35,6±4,0	100,0 / 418,8	0,00 / 6,74	24,4 / 33,8	3,14±0,24 / 1,26±0,16	100,0 / 40,1	0,00 / 6,52	38,9 / 38,8
Euonymus verrucosus Scop.	23,4±1,5 / 36,5±2,6	100,0 / 156,0	0,00 / 4,36	31,0 / 35,9	1,55±0,12 / 0,69±0,06	100,0 / 44,5	0,00 / 6,41	38,8 / 41,9
Sambucus nigra L.	9,6±1,1 / 31,5±4,6	100,0 / 328,1	0,00 / 4,63	19,3 / 25,5	2,55±0,26 / 1,25±0,09	100,0 / 49,0	0,00 / 4,72	17,4 / 12,0
Cornus sanguinea L.	13,4±1,1 / 26,5±1,4	100,0 / 197,8	0,00 / 7,36	42,5 / 22,2	2,51±0,13 / 0,67±0,05	100,0 / 26,7	0,00 / 13,21	25,5 / 28,2
Frangula alnus Mill.	19,1±2,4 / 28,8±2,9	100,0 / 150,8	0,00 / 2,58	28,0 / 20,1	1,36±0,25 / 0,95±0,27	100,0 / 69,9	0,00 / 1,11	41,4 / 56,8
Rhamnus cathartica L.	11,1±1,9 / –	–	–	42,7 / –	3,37±0,65 / –	–	–	47,2 / –
Prunus spinosa L.	17,1±0,9 / –	–	–	23,6 / –	2,46±0,16 / –	–	–	29,1 / –
Rosa canina L.	19,4±1,4 / –	–	–	34,8 / –	1,69±0,12 / –	–	–	34,6 / –
Viburnum opulus L.	12,7±1,4 / –	–	–	24,3 / –	2,50±0,28 / –	–	–	25,5 / –
Crataegus monogyna Jack.	22,6±2,0 / –	–	–	36,1 / –	1,20±0,14 / –	–	–	45,6 / –
Spirea sp.	51,1±1,7 / –	–	–	16,4 / –	0,54±0,03 / –	–	–	25,0 / –

For symbols see Table 1
Confidence interval at α=0,05 is 2,00–2,18

Dielectric parameters of the black elder were studied in the stand edge (control) and when there was 0.5-0.9 hedge (tab.1). An increase of impedance and a reduction of polarization capacity of elder tissues are observed as the hedge increases. Therefore, impedance of the black elder in the stand edge is 5.6 kΩm, and under the forest canopy of the various hedges it is 2.0-3.2 fold higher. Polarization capacity indices of the black elder under the forest canopy are significantly lower – circa 33.4-59.9% – than in the control.

The most favorable growing conditions for black elder are in the stand edge. Under the forest canopy, elder's condition get worse as the hedge increases.

Dielectric parameters variability coefficients of the black elder in the control and in researched alternatives vary between 11.1 and 59.9%. The lowest coefficients are in the control and in the stand of 0.9 hedge.

In order to determine the influence of phytocenosis coefficients on undergrowth species and their persistence, research on dielectric parameters in the open-space and under the forest canopy of 0.7-0.8 hedge was conducted. The results are presented in table 2.

The results presented in table 2 show that impedance parameters of shrubs in the open-space and under the forest canopy differ statistically significantly. The lowest values of impedance and high values of polarization capacity are observed regarding all shrub species in the open-space. Impedance indices of hazel growing under the forest canopy are 39.5% higher, *Euonymus verrucosus* Scop. – 56% higher, alder buckthorn – 50.8%, European spindle – 4 fold higher, black elder – over 3 fold higher, and common dogwood – almost twice fold higher. Polarization capacity indices of hazel growing under the forest canopy were 26.7-69.9% lower than in the control (the open-space). The obtained results indicate lower intensity of shrub metabolic processes under the forest canopy of 0.7-0 hedge than in the open-space. The results show that shrub impedance varies between 11.1 and 51.1 kΩm in the open-space, and polarization capacity between 0.54 and 3.37% (tab. 2). Variability of shrub dielectric parameters varies between 14.9 and 47.2% in the open-space.

5. Conclusion

In the open-space we observed differences in the shrub growth conditioned genetically which indicates influence on electrophysiological characteristics presented in the article. European spindle, black elder, and common buckthorn are characterized by low impedance and high polarization capacity. *Spiraea* and common hazel are characterized by high impedance and low polarization capacity. High variability of impedance parameters and polarization capacity is characteristic for common buckthorn, common dogwood, and common hawthorn. *Spiraea* and common hazel are characterized by low variability of impedance and polarization capacity. The observed differences in electrophysiological characteristics reveal the crucial role of light for the growth, development, and persistence of undergrowth shrubs. I suggest that a quantitative assessment of the electrophysiological characteristics should be undertaken when managing forest stands cultivation and while creating shrub layer.

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